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Black Cottonwood – A Nurse Species for Regenerating Western Redcedar on Brushy Sites

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Black Cottonwood – A Nurse Species for Regenerating Western Redcedar on Brushy Sites

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SUMMARY

Regeneration of coniferous crop species on high brush hazard sites in the Vancouver Forest Region is complicated by vigorous regrowth of deciduous trees and shrubs following harvesting. Brush control measures applied on these sites are expensive and the use of herbicides is often restricted because of site proximity to watercourses or conflicts with other resource values. An alternative approach to regenerating western redcedar is to create mixed plantations that mimic the black cottonwood or red alder communities that develop during primary or secondary succession on these sites. The approach described in this report uses a nurse tree regeneration method where the shading effect of rapidly growing black cottonwood saplings suppresses the vigour of shade-intolerant shrubs, thus providing marginal growth conditions for shade-tolerant conifers such as western redcedar.

To test the nurse tree regeneration method, experimental plantations were established in 1986 at four high productivity, high brush hazard sites and included three treatments (interplanted, brushed and control) at each location. It is too early to draw final conclusions of treatment effects on growth of western redcedar, but the longer term development of the species using the nurse tree approach has been examined in a 10-year old operational nurse tree plantation.

In the experimental plantations, mortality of black cottonwood whips and western redcedar seedlings meant that considerable replanting was necessary to obtain the desired stocking objectives. Deer browse on western redcedar seedlings was moderate to heavy but was not responsible for seedling mortality.

After 10 years, western redcedar saplings averaged 4.0 m in the operational nurse tree plantation. Height growth of western redcedars was greatest for saplings located between 1.5 and 2.5 m from the nearest black cottonwood, and this area has been designated as a zone of minimum growth suppression. The 2.5 m spacing used in the four operational plantations provides a compromise which minimizes the suppressive effects of black cottonwood saplings while maximizing crop tree stocking levels.

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TABLE OF CONTENTS

SUMMARY iii

ACKNOWLEDGEMENTS iv

INTRODUCTION 1

MATERIALS AND METHODS 2

- Site Selection, Description, and Identification 2
- Experimental Nurse Tree Plantations: Establishment, Maintenance, and Measurements 3
- Operational Nurse Tree Plantation: Disturbance History and Measurements 4
- Data Analysis 4

RESULTS AND DISCUSSION 5

- Experimental Plantations 5
  - Vegetation development and response to treatments 5
  - Survival, browsing damage, and growth of western redcedar 6
- Operational Plantation 7
  - Stand structure 7
  - Height growth relationships among black cottonwood, western redcedar, and shrubs 7

SUMMARY 11

LITERATURE CITED 12

TABLES

1 Plantation locations and disturbance histories 2

2 Site quality and initial plant communities at the experimental and operational plantations 3

3 First- and 3rd-year mortality and browse observations for western redcedar seedlings in control, brushed, and interplanted blocks at four experimental plantations 6

FIGURES

1 Natural regeneration of western redcedar under a black cottonwood canopy at a medium bench floodplain site (Ac-Red-osier dogwood site association) 1

2 Layout used in four experimental plantations showing spacing of black cottonwood (•) and western redcedar (°) in control, brushed, and interplanted blocks 4

3 Means and 95% confidence limits for 3-year-old western redcedar seedlings in four experimental plantations 7

4 Plan view of the 10-year-old operational plantation 8

5 Height-age relationships for black cottonwood and western redcedar at the 10-year-old operational plantation 8

6 Relationship between height of western redcedar (Cw) saplings and distance from nearest black cottonwood (Ac) at the 10-year-old operational plantation 9

7 Height-age relationships for western redcedar saplings stratified into two growth zones at the 10-year-old operational plantation 10

8 Projection of the zone of minimum growth suppression for western redcedar under the canopy of 10-year-old black cottonwood 11

INTRODUCTION

Old-growth western redcedar (*Thuja plicata* Donn *ex* D. Don in Lamb.) stands on moist to very moist, nutrient-rich, upland or floodplain sites in coastal British Columbia have characteristically open canopies and well-developed shrub layers. As a result, survival and growth of coniferous plantations on these sites are often hindered or even prevented by fast-growing deciduous woody shrubs (vine maple, red-osier dogwood, black twinberry, thimbleberry, salmonberry, red elderberry) and deciduous trees (red alder, black cottonwood, bigleaf maple, paper birch). Compared to other sites, regeneration success on floodplain sites requires the most intensive control of competing vegetation. The conventional approach to conifer regeneration has been to carry out intensive site preparation treatments (especially blade scarification, hot slash burns, or "brown and burn") and to control post-planting brush using aerial or ground-applied herbicide sprays or manual brushing. However, such intensive site preparation and stand tending is expensive, and the use of herbicides is often prohibited because of their potential impact on fisheries, wildlife, and water resources and because of public concerns.

Ecological survey data (Orloci 1961, 1964, 1965; B.C. Forest Service 1975-1985, data on file in the Vancouver Forest Region) and field observations suggest that western redcedar could be regenerated on high brush hazard sites if the natural processes of species recruitment were imitated (Figure 1). The hardwood overstory effectively suppresses the growth of shade-intolerant shrubs by reducing their cover and vigour, to an extent that provides at least marginal conditions for the survival and growth of shade-tolerant conifers. This has been the rationale for using non-crop tree species as nurse species (Ford-Robertson 1971) in forest plantations to encourage regeneration of crop species on some sites or in some situations (see e.g., Mitchell and Chandler 1939, Polansky 1966, Kantor 1975, Mayer 1977, Rohrig and Gussone 1982, and Smith 1986). In British Columbia, Klinka and Krajina (1986) recommended a mixed planting of blackcottonwood and western redcedar as a method for regenerating the latter species on high brush hazard, alluvial sites in the Malcolm Knapp Research Forest.

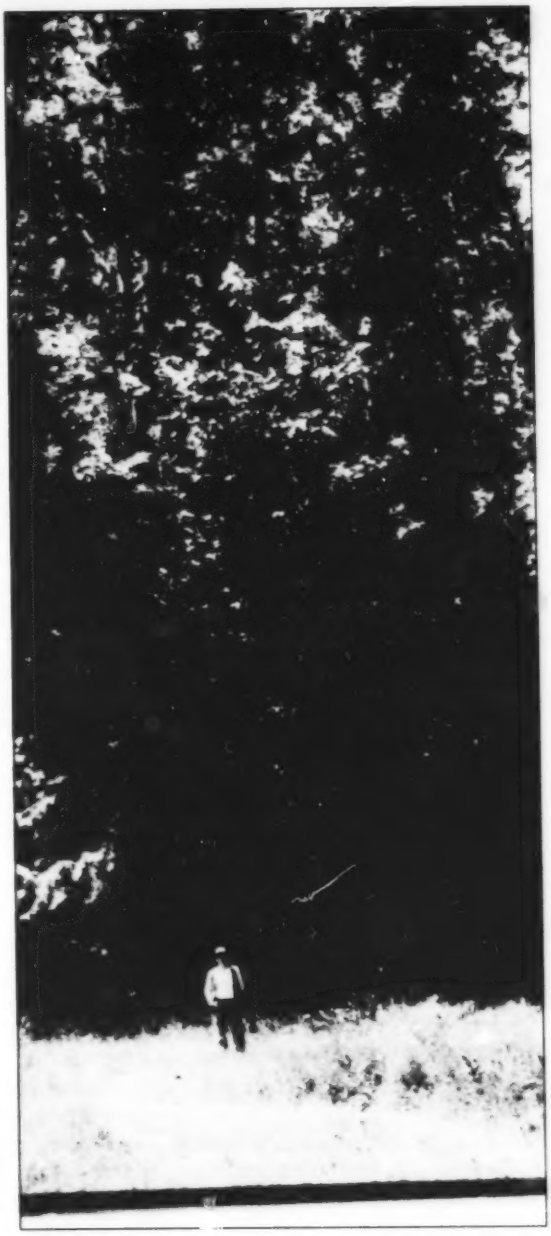

FIGURE 1. Natural regeneration of western redcedar under a black cotton-wood canopy at a medium bench floodplain site (Ac-Red-osier dogwood site association).

To test the nurse tree regeneration method in a controlled situation, a nurse tree experiment was established as a part of the FRDA 2.07 research project "Environment-Growth Relationships of Black Cottonwood on Alluvial Floodplains in Coastal British Columbia". The main objectives of this experiment were to establish several nurse tree plantations, and to compare the growth of western redcedar interplanted with black cottonwood to the seedling growth in plots brushed monthly and in control plots. The intensive brushing treatment is not proposed here as an operationally-feasible brush control method. Monthly brushing was used to ensure that no overtopping of conifers occurred so that height growth of interplanted and control western redcedar seedlings could be compared to western redcedar seedlings growing in full sunlight. Black cottonwood was chosen as a nurse species because of its rapid initial growth; western redcedar was chosen because of its shade tolerance and suitability as a crop species on moist to very moist, nutrient-rich to -very rich upland and floodplain sites in the CWH zone (Klinka *et al.* 1984). A 10-year old operational plantation of black cottonwood and western redcedar on a floodplain site along the Chilliwack River also allowed the study of the longer-term development of a mixed planting of the two species. This report discusses the feasibility of the nurse tree regeneration method, using the 3-year results from the four experimental plantations and the spatial relationships and growth rates in the 10-year operational plantation.

MATERIALS AND METHODS

Site Selection, Description, and Identification

Five plantations (four experimental and one operational) were located on high productivity, high brush hazard sites representing a variety of site disturbance histories (Table 1). Two of the sites were located on seepage slopes and three on floodplains with all sites being suitable for growth of black cottonwood and western redcedar. Topographic, soil, and vegetation characteristics were described according to the standard ecological practices and techniques employed by the B.C. Forest Service (Walmsley *et al.* 1980). Using the system of biogeoclimatic ecosystem classification (Pojar *et al.* 1987) and the results of the B.C. Forest Service Coastal Correlation Working Group, we identified site association, series, and type for each site (Table 2). Table 2 also includes a tentative vegetation classification of the early-seral plant communities that occupied the study sites at the time of planting.

TABLE 1. Plantation locations and disturbance histories

Site	Location	History of disturbance
Experimental Plantations		
Research Forest	Malcolm Knapp Research Forest, Haney	Blade brush-cleared, scarified/stumped 1985
Vedder	Vedder Mountain, Chilliwack Forest District	Slashed, slashburned 1985, mechanically brushed 1986
Herrling	Herrling Island, Fraser River, Chilliwack Forest District	Skidder-yarded and drum-chopped/scarified 1985, mechanically brushed 1986
Elaho	Mile 47, Elaho River, Squamish Forest District	Grapple-yarded, slashburned 1982, herbicide 1985, mechanically brushed 1986
Operational Plantation		
Soowahlie	Indian Reservation, Chilliwack River at Sweltzer Creek, Chilliwack Forest District	Skidder-logged 1977, blade-scarified 1978

Soil moisture regime (SMR) descriptors for the two upland sites and soil nutrient regime (SNR) descriptors for all sites are defined in Pojar *et al.* (1987). The SMR of floodplain sites is influenced by overflow and post-flood drainage, which, within the limits of a particular floodplain, depend on the bench height and water-holding characteristics of the soil. In view of its dynamic nature, and to provide a relative index of flooding frequency, we used the prefix **f** (denoting flooding) and **l**, **m**, or **h** (denoting the low, medium, or high bench, respectively) to designate the SMR's in periodically flooded ecosystems. Conventional SMR descriptors that follow the new designations (e.g., fresh, moist, and very moist) describe the behaviour of soil water (especially the depth of the post-flood water table) during the growing season after floods have receded.

TABLE 2. Site quality and initial plant communities at the experimental and operational plantations

Site	Site type[a]	SMR[b]	SNR[c]	Initial plant community
Experimental plantations				
Research Forest	CWHdm/Cw-Ladyfern/*Typic*	Very moist	Rich	no vegetation
Vedder	CWHdm/Cw-Ladyfern/*Loamy*	Moist	Very rich	Thimbleberry-Ladyfern
Herrling	CWHds/Ac-Red-osier dogwood/*Typic*	fm/fresh	Rich	Black Twinberry-White Sweet Clover
Tzeho	CWHms/Ss-Salmonberry/*Typic*	fh/fresh	Rich	Fireweed Moss
Operational plantation				
Soowahlie	CWHxm1/Ss-Salmonberry/*Coarse-skeletal*	fh/fresh	Rich	Cottonwood-Nettle

a The name of a site type consists of three formative elements separated by slashes (/). The second (central) element is the name of a site association. The first element is the symbol of a biogeoclimatic variant or subzone -- together with the central element it forms the name of a site series. The third element is an adjective describing edaphic properties, and, when added to the name of a site series, designates a specific site type.

b SMR -- soil moisture regime (**f** denotes a flooded site, and **l**, **m**, and **h**, denote the low, medium, and high bench sites, respectively. Conventional SMR descriptors (e.g., fresh, moist, very moist, and wet) describe the behaviour of soil water after floods have receded.

c SNR -- soil nutrient regime.

Experimental Nurse Tree Plantations: Establishment, Maintenance, and Measurements

Each experimental plantation was divided into three treatment groups: interplanted, brushed, and control (Figure 2). Except for the Research Forest, all plantations were mechanically brushed before planting. Four hundred western redcedar seedlings (1+1 bareroot) were shovel-planted in a 10 tree x 40 tree arrangement at a spacing of 2.5 m. The interplanted treatment occupied one-half of each plantation (10 trees x 20 trees) where 1.25 m black cottonwood whips were dibble-planted at the centre of each square formed by the western redcedar seedlings, and around the perimeter of that half of the plantation. The brushed block occupied one-quarter of the plantation (10 trees x 10 trees) in which competing vegetation was mechanically brushed monthly over the 1986, 1987, and 1988 growing seasons. The control block occupied the remaining quarter (10 trees x 10 trees) of each plantation.

Western redcedar heights were measured annually by the random sampling of 50 non-border trees. Browsing and mortality were assessed and trees were replanted as necessary. Only seedlings planted in 1986 were measured in 1987 and 1988. Black cottonwood whips had to be replaced at three sites

because of poor survival (Herrling and Research Forest plantations) and accidental slashburning (Vedder plantation). As a result, the 3-year growth of black cottonwood saplings is reported for the Elaho plantation only.

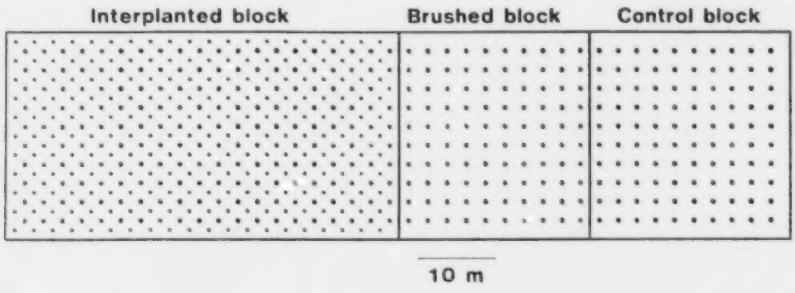

FIGURE 2. Layout used in four experimental plantations showing spacing of black cottonwood (•) and western redcedar (*) in control, brushed, and interplanted blocks.

Operational Nurse Tree Plantation: Disturbance History and Measurements

Before 1977, the operational nurse tree plantation was occupied by a second-growth stand dominated by big-leaf maple, red alder, and black cottonwood, with scattered western redcedar, grand fir, and Douglas-fir. From November 1977 to March 1978, residuals were removed and the remaining trees felled, piled, and burned. Existing brush was piled and burned at the same time and this resulted in complete blade scarification of the site. In March 1978, western redcedar bareroot seedlings (1+1 and 2+0) and rooted black cottonwood and hybrid poplar whips 3 m in length were planted. The survival plot summary conducted 1 year later estimated there were 1785 black cottonwood and hybrid poplar stems per hectare (including a considerable number of naturally regenerated saplings). Western redcedar and grand fir were fill-planted in 1980 to increase stocking levels at the site.

A 15 x 25 m plot was located in an area well stocked with both black cottonwood and western redcedar in the operational plantation so that growth relationships could be examined. A plan view map of the plot was drawn from distance and bearing observations taken from a central point in the plot. For each sapling in the plot, two measurements of canopy width were taken along a N-S and an E-W orientation. The distance from each western redcedar sapling to the nearest black cottonwood tree was determined from the plan map of the plot. Mean shrub heights were estimated to the nearest 10 cm at 1-m intervals along a 25-m transect through the plot. Stem analysis was carried out on 10 randomly selected western redcedars and black cottonwoods to compare growth rates of the two species. Sample saplings were felled and total height and basal age recorded. Western redcedar discs were removed at eight proportionately equal intervals along the stem; black cottonwood discs were sampled at 0.7, 1.3, and 3 m, and then at every 2 m to the top of the sapling. Discs were kiln-dried, sanded, and annual rings counted and digitized.

Data Analysis

Vegetation data were tabulated and synthesized using the VTAB tabling program (Emmanuel 1987). Statistical analyses were carried out and graphs produced with SYSTAT software (Wilkinson 1988). Analysis of probability plots and frequency histograms showed that the seedling height data were normally distributed. Evaluation of plots of standardized residuals against predicted values showed no data transformations were necessary to estimate the ANOVA models. Variation in 3rd-year (1988) heights of western redcedars was analyzed with a 4 (sites) x 3 (treatments) factorial arrangement in a randomized complete block design. ANOVA of western redcedar heights at the time of planting (March 1986) revealed no significant height differences among groups and was not significantly correlated with 3-year growth. Orthogonal contrasts were constructed to compare seedling heights among the various

sites and treatments. Data used in height-age regressions were evaluated for normality and homogeneity of variance, according to the same methods discussed above for the ANOVA models. Height-age regression models were fit with the use of GRAPHER (Golden Graphics 1988) and SYSTAT (Wilkinson 1988) software. Levels of polynomial equations were increased until no significant increase in R^2 was achieved, and, except in one case, no increase in R^2 was observed beyond the linear level.

RESULTS AND DISCUSSION

Experimental Plantations

Vegetation development and response to treatments

Sequential sampling provided an opportunity for examining the early-seral vegetation that developed on the experimental plantations in response to different site preparation histories and monthly brushing. Complete site preparation (scarification, stumping, and ditching) had been carried out at the Research Forest site so that, at the time of plantation establishment in 1986, only six species were found and their total coverage was very small. By the end of 1988, coverage by several graminoids (Pacific common rush, velvet grass, red fescue, fowl blue-grass) was almost 100%. Compared to that in the interplanted and control treatments, the relative frequency of the graminoids in the brushed block was higher and that of shrubs lower. This was characteristic of all experimental plantations. Significant coverage of Pacific common rush, reed canary grass, and small-flowered bullrush indicated the presence of surface water on the site during the growing season. Apparently, the considerable soil compaction (and reduced aeration) on the site was caused by machinery conducting the intense scarification. Precipitation that would have passed through the soil profile was redirected over the surface. This may have been responsible for the poor growth performance and significant mortality of black cottonwood whips in this plantation.

Before planting, a Thimbleberry-Ladyfern community that developed after slashburning occupied the Vedder site. The shrubs (salmonberry, thimbleberry) and most of the herbs (three-leaved foamflower, Siberian miner's lettuce, enchanter's nightshade, tall fringecup) were present on the site before disturbance and resprouted afterwards. Other herbs, such as fireweed and pearly everlasting, colonized the site after slashburning, but these made up only a small percentage of the vegetation cover. By 1988, the herb cover had decreased and the cover of ferns (swordfern, ladyfern) and graminoids (Sitka brome, Dewey's sedge) increased. Monthly mechanical brushing radically decreased shrub coverage and promoted the development of graminoids (Canada wild rye, Sitka brome) and mosses. As a result of an accidental slash fire on the plantation, many of the original whips had to be replanted in 1988, and thus black cottonwood had little coverage at the end of 1988.

The Herrling Island site had been scarified with a Marden chopper before the plantation was established. In 1986, the early-seral community was almost completely dominated by white sweet clover. Given the high coverage of white sweet clover only 1 year after treatment, it is probable that seeds of this species have a long viability in the soil (seed banking) and that these seeds were stimulated to germinate by scarification on the site. By 1988, coverage of white sweet clover decreased and the site was gradually becoming dominated by graminoids such as Canada wild rye and fowl bluegrass. Repeated brushing in 1988 increased coverage of graminoids and mosses and decreased coverage of shrubs and herbs on the brushed blocks. The vigorous growth of white sweet clover following planting caused significant mortality of black cottonwood whips, and replanting was carried out in the spring of 1987. As a result, coverage of black cottonwood was low at the end of 1988.

The Elaho site had been slashburned and the resprouting brush treated with glyphosate before plantation establishment. In 1986, vegetation was dominated by herbs and mosses forming the Fireweed-Moss community. The small, relative decline of these two groups by the end of the 1988 growing season was the result of an increasing coverage of shrubs (thimbleberry, salmonberry, black

raspberry, Pacific trailing blackberry, and Sitka willow) on the site. As at the other experimental plantations, the main difference between vegetation on the control and brushed plots at the Elaho plantation was the increased coverage of graminoids and decreased coverage of shrubs on the brushed plots. Black cottonwood whips grew well over the 3-year period at the Elaho plantation and had a coverage of about 30% with a mean height of 2.1 m (s.d. = 0.36 m, n = 50) at the end of the 1988 growing season.

Survival, browsing damage, and growth of western redcedar

Mortality of western redcedar seedlings was low at all sites after the first growing season, except in the brushed and control blocks at the Herrling plantation (Table 3). At this site, seedlings were damaged during brushing operations in the brushed block. In the control block, all trees planted in a depression had died, which suggests that excessive flooding was the damaging agent. Mortality in the interplanted block at the Research Forest plantation in 1988 was attributed to surface flooding brought about by soil compaction. An accidental fire killed 140 western redcedars at the Vedder plantation, and these were replaced in March 1988.

TABLE 3. First- and 3rd-year mortality and browse observations for western redcedar seedlings in control, brushed, and interplanted blocks at four experimental plantations

Plantation	Treatment	Percent dead		Percent browsed	
		March 87	December 88	March 87	December 88
Research Forest	Control	0	1	27	8
	Brushed	2	2	37	28
	Interplanted	2	15	39	30
Elaho	Control	3	8	24	22
	Brushed	7	3	15	25
	Interplanted	2	5	47	18
Vedder	Control	0	21	84	22
	Brushed	0	6	95	6
	Interplanted	2	5	84	4
Herrling	Control	43	28	4	72
	Brushed	17	10	7	92
	Interplanted	0	6	7	52

Browse damage varied among sites and treatments and from year to year (Table 3). Although all experimental plantations experienced some browse damage, and in many cases seedlings were severely browsed, very little mortality was attributed to browsing effects.

To minimize how browsing pressure might influence the effects of the various treatments on height growth, comparisons for the ANOVA of 3-year western redcedar heights were based on measurements of the 10 tallest seedlings in each site and treatment group combination (Figure 3). All effects were significant in the estimated model. Western redcedar seedlings at the Herrling plantation were significantly shorter than on the other three plantations, where the seedling heights were not significantly different from each other. The low heights recorded at the Herrling plantation may be the result of the very high browse levels observed there (Table 3), so that even the 10 tallest trees were significantly reduced in height by browsing pressure. At the other three experimental plantations, there were no significant differences among plantations and the brushed blocks had significantly taller seedlings in all plantations. As indicated by the significance of the interaction term, the effects were not the same at all plantations. For example, western redcedar seedlings were taller in the control blocks than in the interplanted plots at the Research Forest and Elaho plantations, but the situation was reversed at Vedder. Given the relatively low coverage and thus negligible influence

of black cottonwood in the interplanted blocks after the first three growing seasons, this result showed the expected similarity of western redcedar growth performance in the interplanted and control blocks. Since western redcedar seedlings were tallest in the brushed blocks at the Research Forest, Elaho, and Vedder sites, it appears that monthly brushing increased seedling height growth over 3 years by about 20 cm, compared to those in control blocks.

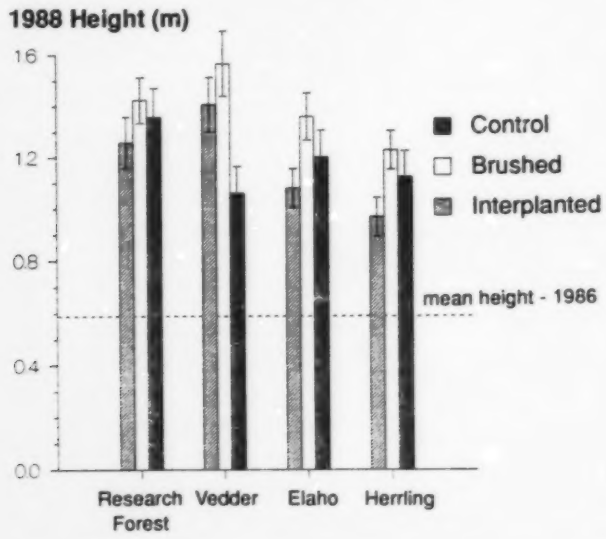

FIGURE 3. Means and 95% confidence limits for 3-year-old western redcedar seedlings in four experimental plantations.

Operational Plantation

Stand structure

A total of 23 black cottonwood and 33 western redcedar saplings were located within the 0.0375-ha plot (613 and 880 stems per hectare, respectively). Black cottonwood saplings grew to an average height of 17.2 m (s.d. = 2.46 m) and western redcedar saplings had an average height of 3.96 m (s.d.= 1.94 m) after 10 years. The plan view drawing of the plot (Figure 4) shows that, 10 years after plantation establishment, the site was well occupied by black cottonwood and western redcedar except where brush was well developed or around brush piles created during scarification (mean shrub height 1.6 m, s.d. = 0.54, n = 25). Shrubs growing in openings in the black cottonwood canopy were generally taller than 2 m in height and had very high coverage (areas of "dense shrubs" in Figure 4). In contrast, the development of shrubs located adjacent to black cottonwood trees was considerably less vigorous (less than 0.5 m in height). From the canopy measurements, we calculated that, 10 years after planting, black cottonwood had 80% net cover, (i.e., not including overlapping canopies). These observations demonstrate the suppressive effects of the black cottonwood canopy on shrub growth.

Height growth relationships among black cottonwood, western redcedar, and shrubs

Height-age regressions derived from stem analysis data for 10 randomly selected black cottonwood and western redcedar saplings manifest the differences in growth rate for the two species (Figure 5). Rooted black cottonwood whips grew quickly and dominated the site with little interference from competing vegetation. Higher variation in height growth rates of the western redcedar population is attributed to the variable suppressive effects of black cottonwood and shrubs.

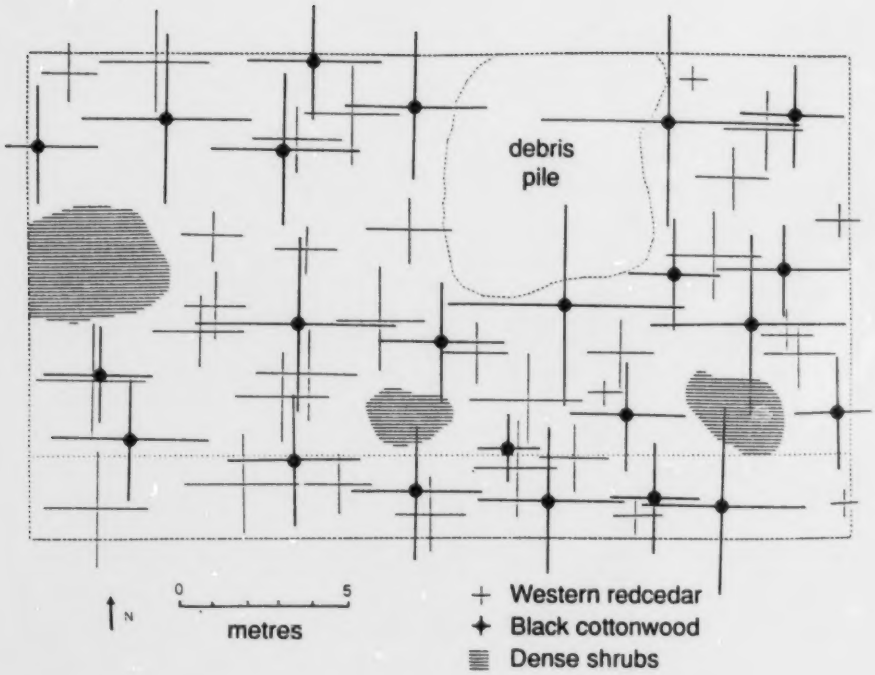

FIGURE 4. Plan view of the 10-year-old operational plantation.

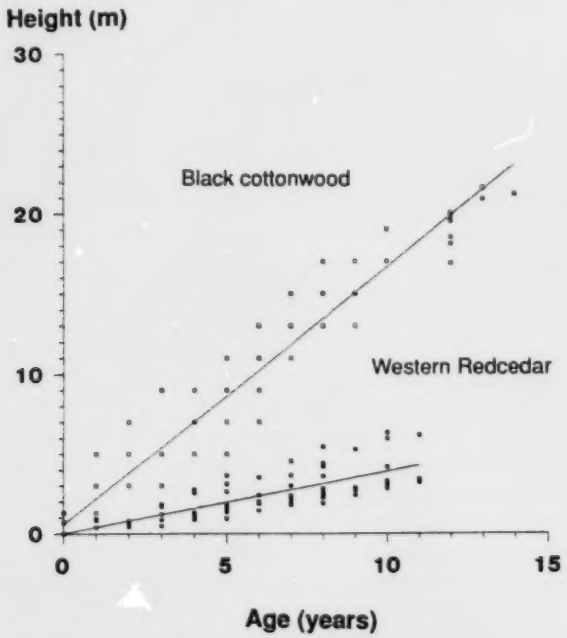

FIGURE 5. Height-age relationships for black cottonwood and western redcedar at the 10-year-old operational plantation.

The polynomial regression in Figure 6 shows the heights of 32 western redcedar saplings within the plot as a function of their distance from the nearest black cottonwood. The relatively low adjusted R^2 of 0.33 expresses the high variability in sapling heights for a given location along the distance axis. Variability in heights of western redcedar saplings is attributed primarily to variation in the widths of black cottonwood canopies. Heights of western redcedars decrease to minimum values between 0.5 and 1.5 m and increase to maximum heights between 1.5 and 2.5 m from the nearest black cottonwood. A t-test comparing heights of western redcedar showed that the mean height of western redcedars growing between 0.5 and 1.5m from the nearest black cottonwood was significantly shorter (mean = 3.01 m, s.d.= 1.11, n = 10) than those between 1.5 and 2.5 m (mean = 4.53 m, s.d.= 1.24, n = 17). This trend suggests the presence and extent of two growth zones for the understory western redcedar: the zones of maximum (0.5-1.5 m) and minimum (1.5-2.5 m) growth suppression. The mean crown radius of the 23 black cottonwood saplings in the plot was 2.0 m (s.d. = 0.58 m), and, since measurements were taken to the ends of the branches along the measurement axes, the zone of maximum growth suppression coincides with the fullest lateral development of the black cottonwood crown.

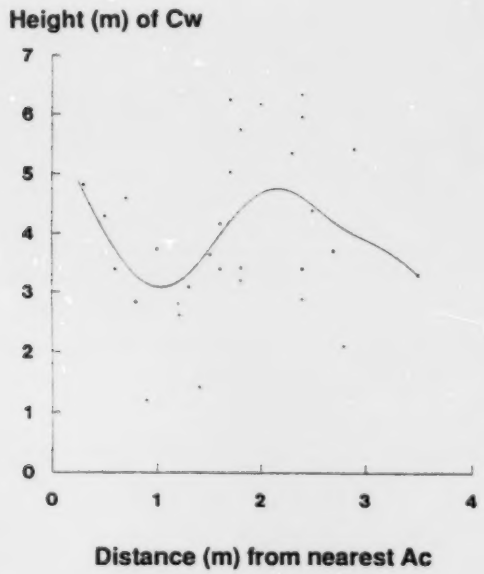

FIGURE 6. Relationship between height of western redcedar (Cw) saplings and distance from nearest black cottonwood (Ac) at the 10-year-old operational plantation.

In the last step, the 10 randomly selected western redcedar saplings used for stem analysis were stratified so that growth relationships between the two recognized growth zones could be compared. The regression analysis included four saplings from within the zone of maximum growth suppression and three from within the zone of minimum growth suppression. The three remaining saplings were located at either less than 0.5 m or more than 2.5 m from the nearest black cottonwood and were not included in the analysis. The F-statistic comparing slopes of the two regression lines was highly significant. Compared to the height-age regression that included all 10 western redcedars (adjusted R^2 = 0.59; Figure 5), the higher adjusted-R^2 values for the two subgroups shown in Figure 7 (0.97 and 0.88 for the zones of minimum and maximum growth suppression, respectively) demonstrate that stratification of western redcedar saplings into two growth zones decreased the unexplained variation

in height-age regression compared to that for the unstratified population. The analysis suggests that differences between the two regressions shown in Figure 7 reflect biologically significant differences in competition for light and/or nutrients between the two growth zones.

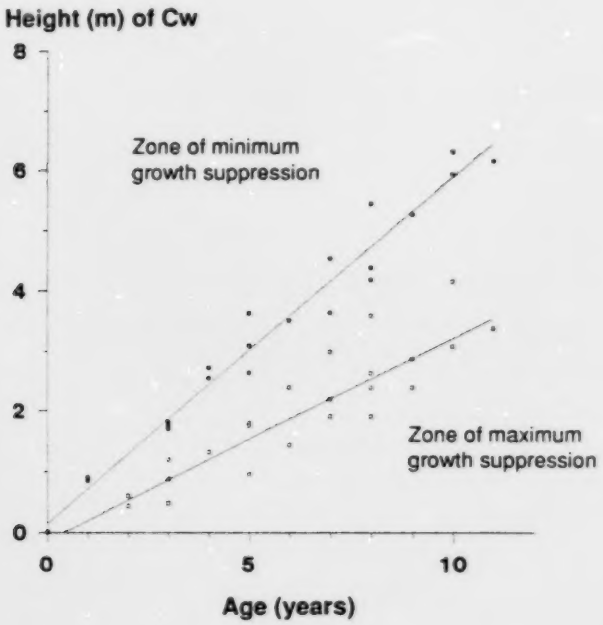

FIGURE 7. Height-age relationships for western redcedar saplings stratified into two recognized growth zones at the 10-year-old operational plantation.

The zone of minimum growth suppression represents the relatively best microsites for western redcedar seedlings. This zone can be used to estimate optimal spacing for nurse and crop trees in interplanted plantations. Take, for example, the 2.5-m spacing arrangement used for the four experimental plantations (Figure 2), and assume growth rates similar to the operational plantation. If a 1.5-m radius circle (corresponding to the boundary between the two growth zones) is drawn around each cottonwood sapling, then, among four adjacent black cottonwoods, there will be a small area of the zone of minimum growth suppression still remaining after 10 years of growth (Figure 8). This suggests that the 2.5 m spacing employed in the four experimental plantations likely provides the most favourable environment for western redcedar growth as nurse tree plantations develop.

Western redcedar saplings can be released when they are well above the shrub layer so that they will not be suppressed by more vigorous shrub growth when the black cottonwood canopy is removed. According to measurements in the operational plantation (mean black cottonwood height 17.2 m; mean shrub height 1.60 m; mean western redcedar height 3.96 m), the black cottonwood canopy on this site could be removed at any time (i.e., after 10 years) without having the western redcedar saplings overtopped by shrubs. It is possible to remove the cottonwoods at a later date if the management intention is to harvest the cottonwood nurse trees. Given the relatively low level of management effort (compared to complete chemical or mechanical brush control) and ecologically benign nature of the nurse tree method, we consider the growth of western redcedar in the black cottonwood understory to be acceptable.

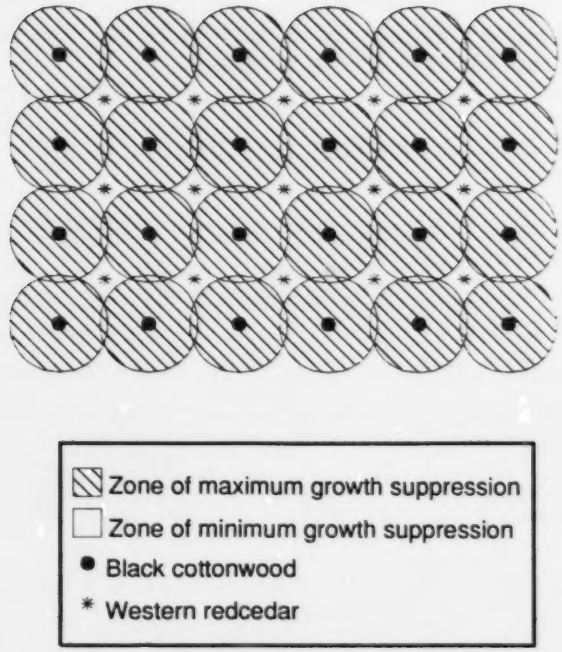

FIGURE 8. Projection of the zone of minimum growth suppression for western redcedar under the canopy of 10-year-old black cottonwood (based on 2.5 m spacing for both black cottonwood and western redcedar and growth rates characteristic for the CWHxm1/Cw-Ss-Devil's Club/Coarse - skeletal site type).

SUMMARY

From the data, the following generalizations can be made about the application of the nurse tree method for regenerating western redcedar on high brush hazard sites in southwestern British Columbia:

1. The nurse tree method of brush control for western redcedar using black cottonwood appears to be effective and deserves more study.
2. Since replanting black cottonwood was required at the experimental plantations this means that 1st- and 2nd-year survival of black cottonwood whips must be closely observed.
3. Severe browse damage on western redcedar seedlings seldom appears to result in mortality.
4. The 3-year brushing treatment promoted the coverage of graminoids and increased height growth of western redcedar by approximately 20 cm, compared to the control and interplanted treatments.
5. The 10-year-old black cottonwood canopy (80% net cover) decreased the cover and vigour of shrubs, and the height growth of understory western redcedar saplings appeared to vary in relation to the distance from the nearest black cottonwood sapling.

6. The best growth of western redcedar occurred in a zone of minimum growth suppression, between 1.5 and 2.5 m from the nearest black cottonwood.

7. The 2.5 m spacing arrangement is likely to be the most suitable for mixed planting of black cottonwood-western redcedar.

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